Attachment 1-6

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FAA 1391b, 1/25/91

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION SPECIFICATION

INSTALLATION, TERMINATING, SPLICING AND SURGE PROTECTION OF UNDERGROUND CABLES.

1. SCOPE

This specification defines the minimum requirements for installation of electrical cables buried directly in the earth or installed in underground duct or conduit. The work includes, but is not limited to, surveying, trenching, backfilling, installation of cables, conduits, ducts, hand holes, manholes, splicing or other joining, terminating and providing surge protection of cables, mandreling of conduits and ducts, testing of cables for acceptability and installation of cable and duct markers. This specification defines, as well, the responsibilities of the contractor with respect to safety, quality assurance and quality control during the installation and the testing of the cable system.

1.1. SCHEDULING of ALL WORK

Airport runways must remain in operation during certain periods. All work will be coordinated during all construction activity so as not to interfere with the functions of the airport. The contractor shall perform all work with a minimum disruption to the FAA and airport operations. Any work performed within five hundred feet (500') of any active runway may require runway closing. Advance notice of at least twenty four (24) hours of proposed work near an active runway must be given to the FAA. All work shall be coordinated with the Airport Manager, Airport Traffic Control Tower, Airport Security and other contractors through the FAA as defined by the contract documents.

1.2. GENERAL

All equipment and materials defined by referenced specifications shall be subject to acceptance through manufacturers' certification of compliance with the applicable specification when so requested. The requirements of this specification shall be considered as minimum requirements and shall not relieve the contractor from furnishing and installing higher grades of materials than specified therein when so required by the contract drawings and specifications. The installation shall conform to the most stringent requirements of the National Electrical Code or local electrical code and shall comply with applicable ANSI and IEEE standards, as well as to other relevant guides and standards listed under Section 2.

1.2.1. Safety during construction and testing. All necessary site works included in the overall scope of works, from delivery to site to final approval, shall be risk assessed with respect to safety. A detailed, site-specific, Safety Risk Assessment shall be submitted by the Contractor to FAA for final approval no less than 3 weeks prior to commencement of on-site works. During construction, installation and testing, the Contractor shall comply with the safety rules of FAA (FAA AC 150/5370-2) and those dictated by OSHA (Part 1926), NEC and ANSI/IEEE. The Contractor shall be held responsible for the implementation of all FAA approved items in the Safety Risk Assessment document.

1.2.2. Quality Assurance. The Contractor shall submit a Quality Plan, in compliance with ISO 9001, "Quality Management Systems Requirements," which will allow FAA to identify the stages at which FAA requires carrying out an inspection or witnessing a test. The Quality Plan shall cover all relevant stages of personnel qualification, design, supplier selection, manufacturers' acceptance testing, site inspection, site quality control testing and commissioning. The Quality Plan shall identify all relevant suppliers by

name, components supplied, country of origin and whether suppliers and supplied components are Quality Assurance Certified.

1.2.3. Quality Control. The quality of the equipment installed shall be controlled at the manufacturers' plants and on-site to ensure that it meets the required specifications. The quality of civil engineering work, such as trenching, ducting, and others, shall be inspected by FAA and approved after all major construction steps. The Contractor shall inform FAA about the manufacturing/shipping schedules and enable representatives of FAA to witness all acceptance tests. These tests shall be performed on a statistically meaningful number of samples, specified by FAA engineers, or on each reel of cable shipped. After receipt of equipment shipments and prior to installation, the Contractor shall subject all equipment to a thorough visual inspection which a representative of FAA may choose to witness. All nameplates and markers shall be checked against the required specifications and any deviations shall be brought to FAA's attention. At FAA's request, quality control checks, including acceptable electrical measurements (such as cable insulation resistance at a minimum voltage level of 5kV, and surge protection leakage current measurements), shall be performed and reported. Finally, after the installation of cable systems is completed, commissioning tests, as stipulated in Sections 4.2 and 4.3, shall be performed.

1.2.4. Qualifications of Personnel. In medium voltage (distribution class) cable installation projects, the design team shall have at least one registered engineer with significant experience in medium voltage design, review and construction management. This registered engineer shall have the ultimate responsibility of the construction set (specifications, drawings, and cost estimates) and the installation quality control. Experienced personnel regularly engaged in this type of work shall do all work. All cable splicing shall be performed only by experienced and qualified Medium/High Voltage Electricians, per Appendix A. Before any cable splices are made, the FAA may request an example splice and/or termination be made to demonstrate their qualifications. In order to qualify the splicer, this example splice and/or termination should comply with the requirements of accessory manufacturers, and pass the requirements of IEEE standards 48, 386 and 404 with respect to partial discharge. The workers shall be properly licensed where required by law.

1.3. EXISTING FAA BURIED CABLE and DUCTS

1.3.1. FAA Documentation. The contract documents define the drawing format used by the FAA to record the location of buried cable and ducts. The contractor shall use the FAA format during the course of work to assure the accurate location of the new installations are described on the FAA drawings for the area of work. The contract documents include copies of the FAA drawings for the area of work.

1.3.2. FAA Marking of Known Buried Cables and Ducts. All known FAA power and control cables leading to and from any operating facility will be marked in the area of work by the FAA for the information of the contractor before starting work. The FAA will mark these cables once for the contractor. It is the contractor's responsibility to

maintain these markings throughout the course of the project. Airport mowers may be expected to be in use by airport personnel throughout the duration of the work.

1.3.3. Other Buried Cables, Ducts, Piping and Items. The contractor shall be responsible for contacting the utilities prior to starting work and for confirming the location of existing utilities and all other items that may be buried in the area of work. The contractor ***must hand dig*** along any area suspected of having utilities of any sort. The airport manager shall be contacted to locate those items owned or known by the airport to exist.

The contractor shall take all precautions to protect existing underground (buried) items including but not limited to; fuel tanks, water lines, cables, ducts and structures. Buried items shall be protected from damage for the duration of work. The contractor shall immediately repair, with equal material by skilled workmen, those items damaged by the contractor or subcontractors work.

Prior approval from the FAA shall be obtained for the materials, workers, time of day or night for making repairs, method of repairs, and for any permanent repairs the contractor proposes to make. In the event of inadvertent damage, the contractor shall immediately stop work and notify the FAA and utility when appropriate. All repair work shall be inspected and approved by the FAA with the concurrence of the affected utility company, airport, or other owner(s) of the damaged item(s).

2. APPLICABLE DOCUMENTS

The document issues in effect on the date of the screening information request for the following documents form a part of this specification.

2.1. Federal Aviation Administration (FAA) Specifications

150/5345-26D	FAA Specification for L-823 Plug and Receptacle, Cable Connectors.
150/5345-7E	FAA Specification for L-824 Underground Electrical Cable for Airport Lighting Circuits.
150/5370	FAA Standards for Specifying Construction of Airports.
FAA-E-2793	Cable, Electrical Power, 500 to 25,000 Volts.
FAA-E-2013	Cable, Electrical Power, 600 to 15,000 Volts.
FAA-E-2042	Cable, Electrical Control, Exterior.
FAA-E-2072	Cable, Telephone, Exterior.

FAA-E-2171	Cable, Coaxial, Armored, M17/6-RG11.
FAA-E-2271	Cable, Coaxial, 50-Ohm, Foam Dielectric, 1/2 and 7/8 Inch.
FAA-E-2524	Cable, Radio Frequency, Foam Dielectric, 1/2 and 7/8 Inch, Corrugated Type.
FAA-E-2619	Cable, Coaxial, RG-35/U, Armored.
FAA-STD-019	Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities

2.2. American Association of State Highway & Transportation Officials

AASHTO	HB-17, Standard Specifications for Highway Bridges.

2.3. American National Standards Institute (ANSI) Standards

ANSI C80	Rigid Steel Conduit – Zinc Coated.
ANSI C119.2	Water Immersion Test.
ANSI C119.1	Sealed Insulated Underground Connector System Rated 600 Volts.

2.4. American Society of Civil Engineers

CI/ASCE 38-02	Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data.

2.5. American Society for Testing & Materials (ASTM)

ASTM A48	Standard Specification for Gray Iron Castings.
ASTM C-478	Standard specification for Precast Concrete Manhole Section (AASHTO No. M199).
ASTM C-990	Standard Specification for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants.

2.6. Institute of Electrical and Electronics Engineers (IEEE) Standards

IEEE-404-1977	Standard for Power Cable Joints.
IEEE-48-1975	Standard for Cable Terminations.

IEEE-386	Standard for Separable Insulated Connector Systems.
IEEE-400.3	Guide for PD Testing of Shielded Power Cables in a Field Environment.
IEEE- 48	Test Procedures and Requirements for AC Cable Terminations 2.5kV through 765kV.
IEEE C62.22	IEEE Guide for the Application of Metal Oxide Surge Arrester for Alternating Current Power Circuits.
IEEE 1299/C62.22.1	Guide for the Connection of Surge Arresters to Protect Insulated, Shielded Electric Power Cable Systems.

2.7. International Electrical Commission (IEC) Standards

IEC 60071-2	Insulation coordination Part 2: application guide.

2.8. National Electric Manufacturers Association (NEMA) Standards

RN 1	Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Steel Conduit.
TC 2	Electrical Polyvinyl Chloride (PVC) Tubing (EPT) and Conduit (EPC-40 AND EPC-80).
TC 3	PVC Fittings for Use with Rigid PVC Conduit and Tubing.
TC 6 & 8	PVC Plastic Utilities Duct for Underground Installation.
TC 9	Fittings for PVC Plastic Utilities Duct for Underground Installation.
TC 14	Filament-Wound Reinforced Thermosetting Resin Conduit and Fittings.

2.9. Occupational Safety and Health Administration

Part 1926	Safety and Health Regulations for Construction.

2.10. Underwriters' Laboratories (UL) Inc. Standards

UL 6	Standard for Rigid Metal Conduit.
UL 514	Fittings for Cable and Conduit

UL 651	Schedule 40 and 80 Rigid PVC Conduit.
UL 1242	Intermediate Metal Conduit

2.11. National Fire Protection Association (NFPA)

NFPA-70	National Electric Code
NFPA-780	Standard for the installation of Lightning Protection Systems

2.12. Military Specification

MIL-I-3825	Insulating Tape, Self-Fusing
MIL-C-38359	Cable, Power, Electrical, Airport Lighting

2.13. Federal Specifications

AA-59544	Cable and Wire, Electrical (Power, Fixed Installation)
W-C-582	Circuit Breakers, Molded Case; Branch Circuit and Service
W-C-582	Conduit, Raceway, Metal, and Fittings; Surface
W-C-586	Conduit Outlet Boxes, Bodies, and Entrance Caps, Electrical: Cast Metal - For Shore Use
W-C-1094	Conduit and Conduit fittings; Plastic, Rigid
W-J-800	Junction Box; Extension, Junction Box: Cover, Junction Box (Steel, Cadmium or zinc - Coated)
W-S-610	Splice, Connector
W-S-865	Switch, Box (Enclosed), Surface Mounted
WW-C-540	Conduit, Metal, Rigid: and Coupling, Elbows, and Nipple, Electrical Conduit: Aluminum
WW-C-563	Conduit, Metal, Rigid: Electrical, Thin Walled Steel Type (Electrical Metallic Tubing); Straight Lengths, Elbows, and Bends
WW-C-566	Conduit, Metal, Flexible

WW-C-581	Conduit, Metal , Rigid; and Coupling, Elbow and Nipple, Electrical Conduit: Zinc Coated
QQ-W-343	Wire, Electrical, (not insulated)

3. EXCAVATION AND TRENCHING

3.1. GENERAL

Where turf is well established and sod can be removed, it shall be carefully stripped, properly stored and restored. Any excess excavated material shall be removed in accordance with the contract documents.

When rock is encountered, it shall be removed to a depth of three inches (3") below the required trench depth and shall be replaced with a bedding material of earth or sand containing no material aggregate particles that would be retained on a quarter inch (1/4") sieve. When ledge is encountered, the FAA shall be consulted regarding alternatives such as re-routing or transition to overhead lines.

3.2. DEPTH REQUIREMENTS

Unless otherwise specified by the contract documents, all cables, ducts, and conduits shall be installed as follows:

a. All cables, conduits and ducts shall be buried to the minimum depth to their top as specified by the following paragraphs b, c, d, and e when these specified depths are below the frost line for the location. The frost line depth, when deeper than the minimum depths listed, shall be the depth to the top of the cable, conduit or duct.

b. Direct-earth burial cables shall be a minimum of twenty four inches (24") below finished grade when on airport or government controlled property, and thirty six inches (36") below finished grade when off airport or government property unless local conditions and regulations require deeper burial, in which case the Contractor shall advise FAA about these regulations before proceeding with the construction. If finished grade has not been established before the cable trenches are excavated it is the contractors responsibility to determine what the final finished grade elevation will be and excavate the trench deep enough to meet the depth requirements at the end of the project. Cables shall not be direct buried under paved areas, roadways, railroad tracks, or ditches.

c. Underground ducts shall be installed so that the tops of all such ducts are a minimum of eighteen inches (18") below finished grade. Should the frost line be deeper than the installed ducts, Contractor shall, after FAA approval, install deflection couplings where conduits protrude above ground, in order to mitigate frost heave. Should local conditions require unusually deep burial of ducts, Contractor shall discuss the situation with FAA and obtain approval. Underground ducts under paved areas, roadways, railroad tracks, or ditches shall be either rigid steel conduit or concrete-encased PVC or steel conduit as defined by the contract documents.

d. Concrete-encased duct or rigid steel conduit shall be installed so that the top of the concrete envelope or conduit is not less than eighteen inches (18") below the bottom of paving when installed under runways, taxiways, and other paved areas; and not less than eighteen inches (18") below finished grade when installed in unpaved areas.

e. When cable is routed under railroad tracks, it shall be rigid steel conduit or concrete encased duct with the top of the duct not less than forty two inches (42") below the base of the rail.

3.3. BACKFILLING

Backfilling shall not be completed until the surveying is complete. Trenches shall not be excessively wet and shall not contain pools of water during backfilling operations. Trenches shall be completely backfilled and tamped level with the adjacent surface. When necessary to obtain the desired compaction, backfill material shall be moistened or aerated. When sod is to be placed over a trench, backfill shall be stopped at a depth equal to the thickness of the sod to be used. All excess excavated material shall be removed in accordance with the contract documents.

3.4. RESTORATION

Where sod has been removed it shall be replaced as soon as possible after the backfilling is completed. All areas disturbed by the trenching, storing of dirt, cable laying, pad construction, and other work shall be restored to the original condition. Restoration shall include any necessary grading, fertilizing, liming, seeding, sodding, sprigging or hydro mulching as required to restore the disturbed area to match the adjacent area. Where trenching cuts through paved areas, the surface shall be properly backfilled and resurfaced with paving similar to the original paving. Resurfaced areas shall be level with original paving, free from cracks and capable of withstanding full traffic loads without settling or cracking. The contractor shall be responsible for maintaining all disturbed and restored surfaces until final acceptance by the FAA

3.5. CONDUIT

Rigid-metal conduits may be direct earth buried. Rigid non-metallic conduits shall be concrete encased unless direct burial without concrete encasing is specified by the contract documents. All rigid-metal conduit shall terminate with an O.Z. Type BLG insulated ground bushing and double locknut at each underground or cabinet box termination. In exterior locations, exposed threads of metal conduit shall be protected using a zinc-rich cold galvanizing compound.

3.5.1. Boring Conduit or Casing. Conduit or castings required under roadways or railroads shall be installed by boring. Jacking of conduit is not allowed. Conduits bored under roads off airport property shall be a minimum of thirty six inches (36") below finished grade.

3.6. DIRECT BURIED CABLES

3.6.1. Excavation. The contractor shall excavate all trenches for direct-earth burial cable as follows:

a. To the depth specified in paragraph 3.2.

b. To a width of not less than six inches (6") for single or multiple runs of power, or control and signal cable.

c. To a width and depth, which will provide horizontal or vertical separation of power cables as specified in paragraphs 3.9.2 and 3.12 from other power cables or different voltage ratings, or from power cable and any control or signal cable.

d. Backfill shall be firmly tamped in the separation area.

Unless otherwise specified, all cables in the same location and routed in the same general direction shall be installed in the same trench. Trenches for cables may be excavated manually or with powered trenching equipment. Walls of trenches shall be essentially vertical so that a minimum of shoulder surface is disturbed. The bottom surface of trenches shall be essentially smooth and free from coarse aggregate. Unless otherwise specified, trenches shall be opened only for the time required to install, inspect and survey the cables. The trench shall be closed in the same working day or marked, barricaded and/or lighted according to current Airport specifications and requirements.

3.6.2. Backfill for Direct Buried Cable. After underground cable has been installed and surveyed, the trench shall be backfilled. The first layer of backfill shall be 3 inches deep, loose measurement, and shall be either earth or natural sand containing no material aggregate particles that would be retained on a one quarter inch (1/4") sieve. This layer shall not be compacted, except as noted in paragraph 3.4.1.1. The second layer shall be 9 inches deep, loose measurement, and shall contain no particles that would remain on a one inch (1") sieve. The remainder of the backfill shall be excavated or imported material and shall not contain stone aggregate larger than 4 inches maximum diameter. The second and subsequent layers shall be thoroughly tamped and compacted to the density of the adjacent undisturbed soil.

3.7. UNDERGROUND DUCTS

All underground ducts shall be: (a) PVC coated (inside and outside) rigid-metal conduit conforming to NEMA RN 1, or (b) Rigid non-metallic conduit (duct) conforming to UL 651, NEMA TC 6&8 with fittings conforming to NEMA TC 9 or conforming to NEMA TC 14.

3.7.1. Duct Size, Material, and Installation. Ducts shall be of the size, material, and type indicated on the contract documents. Standard precast spacers shall be used for duct support and alignment. Where no size is indicated on the drawings or specifications, the ducts shall not be less than 4 inches inside diameter. All duct lines shall be laid to slope toward hand holes, manholes and duct ends for drainage. Grades shall be at least three inches (3") per hundred feet (100'). On runs where it is not practicable to maintain the slope all one way, the duct line shall be sloped from the center in both directions toward

manholes, hand holes or duct ends. Pockets or traps where moisture may accumulate shall be avoided.

3.7.2. Manholes and Hand Holes

3.7.2.1. Manhole Construction

Manholes shall be precast reinforced concrete of the size and shape as detailed on the contract drawings and conform to ASTM C-478. Manholes shall consist of two (2) sections, joined at the site to provide a watertight joint with a preformed flexible sealant in conformance with ASTM C 990. A twelve inch (12") diameter sump, four inches (4") deep shall be cast in the center of the manhole floor.

Live loading shall be for H 20 loading per A.A.S.H.T.O. Standard Specifications for Highway Bridges. Design wheel load shall be a minimum of 32,000 pounds. The live load shall be that loading which produces the maximum bending and shear moments in the structure.

Pulling irons, capable of withstanding eight thousand pounds (8000 lbs) of pull shall be set in the concrete wall opposite each duct bank entrance at the locations indicated on the contract drawings. Pulling irons shall be McGraw-Edison Cat. No. DU1T1 or approved equal.

Manhole frame and cover shall be gray cast iron, conforming to ASTM A48-76, heavy duty type, similar and equal to Neenah Cat. No. R-1754-A. Cover shall be lettered as indicated on the contract drawings.

Formed duct terminators, similar and equal to Formex, with watertight membranes at shoulders shall be provided for each duct bank entrance. The location of duct bank entrances for each manhole shall be as indicated on the contract drawings. Entrances shall be closed with locking caps, inside and outside to prevent entrance of moisture and foreign materials.

Rebar flange couplers, four and a half inch (4&1/2") shall be provided at the corners of each duct entrance indicated on the contract drawings for extending half inch (1/2") reinforcing bars into concrete duct encasement.

Cable racks and cable support arms shall be furnished in the quantities and locations indicated by the contract drawings for each manhole.
Two acceptable manufacturers of precast manholes are Brooks Precast Concrete products and Dalworth Quickset Company.

3.7.2.2. Manhole Installation

a. The top of the completed manhole shall be set above finish grade in unpaved areas to prevent water from ponding on the manhole. A one eighth inch (1/8") per foot fall from the manhole top to finish grade, ten feet (10') from each edge of the manhole is adequate.

b. When soil load bearing capacity allows the total dead weight of the assembled manhole plus the designed live load to be supported the manhole lower half shall be set on a four inch (4") bed of crushed stone on undisturbed earth. The contract drawings will define any additional requirements.

c. Coat all unused rebar couplers with suitable waterproofing material. Extend four (4) half inch (1/2") rebars from each rebar coupler to at least two feet (2') beyond undisturbed earth into duct encasement concrete.

d. Backfill around the manhole in lifts commensurate with the soil and compact each backfill lift to the density of the surrounding earth.

3.7.2.3. Hand Hole Construction
Hand holes shall be of precast concrete construction of the size and shape as detailed on the contract drawings.

Live loading shall be for H 20 loading per A.A.S.H.T.O. Standard Specifications for Highway Bridges. Design wheel load shall be a minimum of 32,000 pounds. The live load shall be that loading which produces the maximum bending and shear moments in the structure. Hand hole frame and cover shall be gray cast iron, conforming to ASTM A48-76, heavy duty type, similar and equal to Neenah Cat. No. R-1754-A. Cover shall be of the size and location and lettered as indicated on the contract drawings.

Formed duct terminators, similar and equal to Formex, with watertight membranes at shoulders shall be provided for each duct entrance. The location of duct entrances for each hand hole shall be as indicated on the contract drawings. Entrances shall be closed with locking caps, inside and outside to prevent entrance of moisture and foreign materials.

Rebar flange couplers, four and a half inch (4&1/2") shall be provided at the corners of each duct entrance indicated on the contract drawings for extending half inch (1/2") reinforcing bars into concrete duct encasement.

3.7.2.4. Hand Hole Installation
a. The top of the hand hole shall be set above finish grade in unpaved areas to prevent water from ponding on the hand hole. A one eighth inch (1/8") per foot fall from the manhole top to finish grade, ten feet (10') from each edge of the manhole is adequate.

b. When soil load bearing capacity allows the total dead weight of the hand hole plus the designed live load to be supported the hand hole shall be set on a four inch (4") bed of crushed stone on undisturbed earth. The contract drawings will define any additional requirements.

c. Coat all unused rebar couplers with suitable waterproofing material. Extend four (4) half inch (1/2") rebars from each rebar coupler to at least two feet (2') beyond undisturbed earth into duct encasement concrete.

d. Backfill around the hand hole in lifts commensurate with the soil and compact each backfill lift to the density of the surrounding earth.

3.7.3. Manhole and Hand Hole Penetrations. Where a steel conduit penetrates a wall of a manhole or hand hole, a grounding bushing shall be installed. These grounding bushings shall be connected to each other and to the earth ground system with 6 AWG tinned bare copper conductors. All conduits entering a junction box or other electrical cabinets from underground shall be sealed with 3M "Ductseal" or equal conduit sealant. Expanding foam sealants are not allowed for this purpose. All conduit connections to exterior boxes, electrical cabinets or switches shall be made with weatherproof hub fittings.

3.7.4. Mandrel Requirements. The contractor shall mandrel each duct or conduit installed and each existing duct or conduit in which cable is installed or replaced. An iron-shod mandrel, not more than one-quarter inch (1/4") smaller than the bore of the duct or conduit shall be pushed through with jointed conduit rods. The mandrel shall have a leather or rubber gasket slightly larger than the duct inside diameter.

3.7.5. Spare Ducts. All spare ducts installed by the contractor shall be provided with 10 AWG copper-clad steel pull wires for metal conduit or polyolefin pull lines with a minimum tensile strength of 200 pounds for non-metallic conduit. The open ends of all spare ducts shall be sealed with removable tapered plugs, of a type recommended by the duct manufacturers. The plug shall be adapted to firmly secure the pull wire.

3.7.6. Duct Protection. All ducts shall be securely fastened in place during construction and progress of the work, and shall be plugged daily at the end of work to prevent entrance of foreign material. Any duct section having a defective joint shall not be installed.

3.7.7. Ducts Encased in Concrete. All concrete encased ducts shall be placed on a layer of concrete not less than 3 inches thick prior to its initial set. Where two or more ducts are encased in concrete the contractor shall space them at not less than one and a half inches (11/2") (measured from outside wall to outside wall) using spacers applicable to the type of duct. As the duct laying progresses, concrete not less than three inches (3") thick shall be placed around the sides and top of the duct bank. End bells or couplings shall be installed flush with the concrete encasement where required. Interlock spacers shall be used every five feet (5') to ensure a uniform spacing between ducts.

All bottom spacers shall be secured to nominal one inch (1") boards to prevent sinking and overturning. All joints in adjacent ducts shall be staggered a minimum of twenty four inches (24") apart and shall be made completely waterproof prior to covering with concrete.

3.7.8. Ducts Without Concrete Encasement. Trenches for single-duct lines shall be no less than six inches (6") or more than twelve inches (12") wide, and the trench for two or more ducts installed at the same level shall be proportionally wider. Trench bottoms for ducts without concrete encasement shall be made to conform accurately to grade to provide uniform support for the duct along its entire length. A three inch (3") layer of bedding material shall be placed around the ducts. The bedding material shall contain no particles that would be retained on a half inch (1/2") sieve. The bedding material shall be tamped until firm. When two or more ducts are installed in the same trench without concrete encasement, they shall be spaced not less than two inches (2") apart (outside wall to outside wall) in a horizontal direction or not less than six inches (6") apart (outside wall to outside wall) in a vertical direction.

3.8. INSTALLATION OF CABLES

Wherever possible, cable shall be installed from connection to connection in one piece without splices. When necessary, the number of splices shall be minimized. The contractor shall provide a schedule for laying each reel of cable and splice locations for approval of the FAA through the contracting officer prior to installing any cable. The schedule shall be based on the use of the longest practical lengths of cable to minimize the number of splices.

a. When cable cutting is required, cable ends shall be effectively sealed against moisture immediately after cutting. The FAA shall approve the method of sealing. Bends of a radius less than eight (8) times the diameter for rubber-covered or plastic-covered cable, or twelve (12) times the diameter for metallic armored cable, shall not be made. Cable that has been kinked shall not be installed.

b. When unreeling, an observer shall be stationed at the reel to report any cable irregularities. Unless specifically stated in the plans, cables for installation in ducts or for direct burial shall comply with FAA-E-2013D and FAA-E-2793A. Grounding conductors, where required, shall be a minimum size of 6 AWG bare tinned copper wire.

3.9. DIRECT EARTH BURIAL CABLE

3.9.1 Installation in Trench. Direct earth burial cable shall be unreeled in place in the open trench or adjacent to the trench, and carefully placed in the trench bottom. Pulling the cable into the trench or dragging it over the ground will not be permitted. All risers shall have weather heads installed. Each weather head shall have drip loops.

3.9.2. Separation of Cables. Separation between direct earth burial cables shall be as follows:

a. Power cables may be laid together in the trench without separation.

b. Power cables shall be separated a minimum of six inches (6") from all control and signal cables. The actual separation, for each specific case, shall be stipulated by the FAA Engineer.

c. Control and signal cables may be in the same trench without separation from each other.

d. Backfill separating cables shall be firmly tamped.

e. Where cables of different types (i.e., power and control or signal) or different voltages are jointly installed as stated in (a) through (c) above, the individual cables or groups of the same type cables shall be clearly and unambiguously identified by installing metal tags indicating the type (power, control or signal) and voltage for power cables. These tags should be installed in accordance with paragraph 3.7.

3.9.3. Slack Loop. A cable slack loop of three feet (3') diameter shall be left on each end of the cable runs, at all splices, and at all ductbank entries or exits. The slack loop shall be installed at the same minimum depth as the cable run. Loops shall have no bends with an inner radius less than twelve times the outside diameter of the cable. Where cable is brought above ground, additional slack left above ground shall be as shown by the drawings or as directed by the FAA. Cable loops shall not be installed on coaxial cable. Joints in coaxial cables shall be made in accordance with the contract specification.

3.10. CABLE INSTALLATION IN DUCT OR CONDUIT

The contractor shall verify that the duct is open, continuous, and clear of debris or blockage (mandrel 3.7.3) before installing cable. Cable shall be installed in a manner to prevent harmful stretching of the conductor, injury to the insulation, or damage to the outer protective covering or conductor insulation. All cable ends shall be sealed until connections are made. Where more than one cable is to be installed in one duct, all cable shall be pulled at the same time. In no case shall a splice be pulled into a duct or conduit.

3.11. CABLE PULLING

The apparatus used to pull cable at the entrance to a manhole shall be a pulling tube or shall consist of a framework and two sheaves, the diameter of the sheaves being at least ten times that of the diameter of the largest cable. Cable installation may be pulled by a power winch or by hand. Adequate cable pulling compound shall be used. The FAA shall approve the pulling compound. Petroleum grease shall not be used.

When pulling at a bend, the recommended maximum sidewall pressures for 15kV class and less is 500 lbs/ft. For cable voltage ratings greater than 15kV class, the maximum

recommended sidewall pressure is 300 lbs/ft. Consult the cable manufacturer prior to using higher values than these recommendations.

The surface of any cable sheath or jacket shall not be damaged to a depth greater than one tenth ($1/10^{th}$) the original thickness or be flattened out-of- round more than one tenth ($1/10^{th}$) of the outside diameter

a. Table I lists the maximum pulling tensions for commonly installed cables. Maximum pulling tensions for cables not listed in this table shall be obtained from the cable manufacturer.

b. The limitations in Table I do not preclude the use of steel or wire rope for cable pulling. A dynamometer graduated to indicate the tension on the cable being pulled can be used, or the contractor shall adapt a rope harness properly sized to limit pull tension to the value indicated. Any combination of a group of cables to be pulled into a duct shall not exceed the sum of individual allowable tension of each cable plus 15 percent.

c. To minimize splicing, the longest practicable lengths of cable shall be pulled into the ducts at one time. Unless otherwise specified, manholes and hand holes should be as far apart as practicable for the type of cable installed. Under no condition should the distance between hand holes or manholes exceed six hundred feet (600'). The maximum cable length and maximum pulling tension shall be obtained from the cable manufacturer.

Table I. Maximum Allowable Non-Armored Cable Pull
Using Dynamometer or Rope

CABLE	TENSION (Pounds)	ROPE DIAMETER (INCHES) Cotton	Manila	Dacron	Nylon
2 - 1c #8 Solid	275	3/16			
3 - 1c #8 Solid	367	1/4	3/16		
4 - 1c #8 Solid	550		1/4		
2 - 1c #6 Stranded	420	1/4	3/16		
3 - 1c #6 Stranded	630	5/16	1/4		
4 - 1c #6 Stranded	840	3/8		3/16	
1 - 2c #8 Stranded	305	1/4			
1 - 3c #8 Stranded	395	1/4			
1 - 4c #8 Stranded	585		1/4		
1 - 2c #6 Stranded	455	1/4	3/16		
1 - 3c #6 Stranded	685	5/16			
1 - 4c #6 Stranded	880	3/8	5/16	3/16	
1 - 6c #12 Stranded	315	1/4			
1 - 12c #12 Stranded	630	5/16			
1 - 12PR #19 Solid	230	3/16			
1 - 25PR #19 Solid	541		1/4		
1 - 50PR #19 Solid	1061	7/16			3/16
1 - 100PR #19 Solid	2000		15/32	5/16	
RG -11/U	85	3/16			
RG-213/U (RG-8/U)	125	3/16			
RG-214/U (RG-9/U)	145	3/16			
RG-216/U (RG-13/U)	135	3/16			
RG-217/U (RG-14/U)	250		1/4		
RG-218/U (RG-17/U)	800	7/16			

3.12. SEPARATION of CABLES

Separation of cables installed in conduit or duct shall be as follows:

a. Power cables of the same circuit shall be installed in the same conduit or duct.
b. Conductors of circuits rated 600 volts, nominal, or less, ac circuits, and dc circuits shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. All conductors shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway. (NEC 300.3 C 1)
c. Conductors of circuits rated over 600 volts, nominal, shall not occupy the same equipment, wiring enclosure, cable, or raceway with conductors of circuits rated 600 volts, nominal, or less unless otherwise permitted in NEC 300.3 (C)(2)(a-e)
d. Control and signal cables may be installed in the same conduit or duct.
e. Power cables may be installed in the same conduit or duct systems with control and signal cables, but power cable shall be installed in a different duct separated a minimum of three inches (3"), outside wall to outside wall, from ducts that contain control and signal cables. Power cables rated more than 600 volts shall be separated from control and signal cables to the maximum extent possible in the duct system.

3.13. CABLE INSTALLATION IN MANHOLES

Power and control cables shall be installed in separate manholes unless otherwise specified by the contract documents. If space is available, cable slack sufficient for one splice for each cable shall be left in each manhole. Elimination or shortening of slack lengths shall require approval by the FAA.

3.13.1. Separation of Cables in Manholes. When it is not possible to install power and other cable types in separate manholes, they shall be installed on opposite sides of the manhole. In addition, the entire exposed length of all control and signal cables shall be fireproofed by applying a one quarter inch (1/4") minimum thickness of arc-proofing 3M No. 7700 or equal, in accordance with the manufacturer's instructions.

a. Where cables of different types (i.e., power and control or signal)or different voltages are jointly installed as stated in a. through e. of paragraph 3.12., the individual cables or groups of same type cables shall be clearly and unambiguously identified by installing metal tags indicating the cable type(power, control or signal), number of conductors, and voltage for power cables

b. Where it is suspected that interference to signal or control lines may be caused by their proximity to power cables, the control or signal cables and/or the power cables shall be shielded. These shields shall be grounded in accordance with FAA-STD-019.

3.13.2. Cable Racking. Cable racks in manholes and handholes are furnished under manhole/handhole specifications. These racks shall be either made of plastic or galvanized steel provided with porcelain insulators. Cables shall be carefully formed on

the racks around the interior of manholes or handholes, avoiding sharp bends or kinks. All splices and cables shall be tied to cable racks using one eighth inch (1/8") nylon line. Splices shall be a minimum of two feet (2') from the mouth of the duct opening into the manhole or handhole. Where this is not possible, splices shall be located as advised in the manhole/handhole specification or drawing. Splices in different cables shall be staggered.

3.14. CABLE TERMINATION, SURGE AND FAULT PROTECTION

3.14.1. Cable Termination. All control and signal cables shall be terminated as specified. All power cable terminations rated above 4,000 volts or with an outer shield shall be made with an approved stress-relief device. All cable terminations shall be of a pre-fabricated design and their installations shall strictly conform to manufacturer's installation recommendations. Special care shall be exercised to utilize the proper ratings and physical dimensions.

3.14.2. Surge Protection. For low voltage power and control cables, surge protection devices (SPD) shall be applied in accordance with FAA-STD-019e. Medium voltage cable surge protection shall be implemented according to the following guidelines:

a. If a distribution transformer is fed from an overhead line by means of a medium voltage cable, surge arresters of the metal-oxide varistor (MOV) type shall be installed at the pole top and at the transformer between each phase and ground. The pole type arrester shall be of the intermediate class, while the transformer surge arrester shall be of the distribution type. The continuous voltage rating of the arresters shall be determined in a protection and insulation coordination study. As a further protection against direct lightning, intermediate arresters shall be installed one span before and after the interconnection of transformer. Surge arrester leads connecting to cable conductor and grounded metal shield must be as short as possible to minimize the protective voltage level. This recommended surge protection scheme is illustrated in Figure 1.

b. If a distribution transformer is fed from a station transformer directly by means of a medium voltage underground cable, a distribution arrester shall be installed at both ends of the cable in accordance to the guidelines provided in paragraph (a) above.

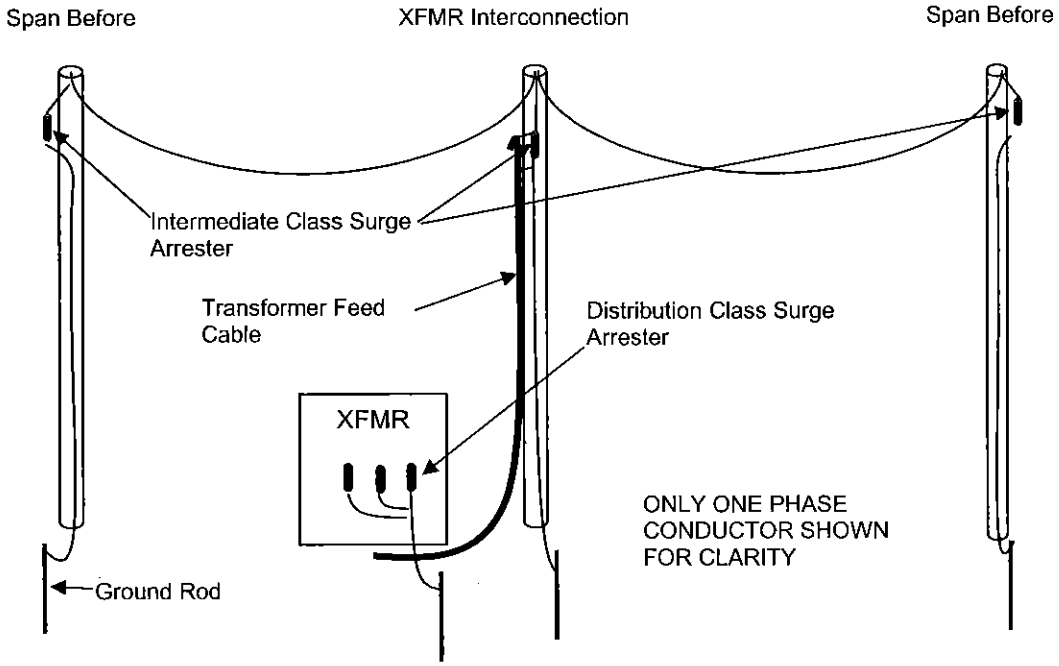

Figure 1. Schematic representation of recommended surge protection system.

3.14.3. Fault Protection. Fused sectionalizers shall be employed to protect the power cable system as a whole from electrical faults. This will be accomplished by isolating faults to single facilities versus multiple facilities (i.e., "daisy chained"). Where existing power cable layouts do not employ proper isolation of faults, sectionalizers shall be added to provide proper fault isolation.

Similarly, transformer primaries in a given electrical line distribution (ELD) service shall not be connected in parallel such that any single power cable or transformer failure will remove power from multiple facilities in the ELD service, or disable the entire ELD service.

3.15. CABLE GROUNDING

Cable grounding shall comply with FAA-STD-019e, namely:

a. Shields on shielded power cables shall be grounded at each end. The grounding conductor shall be 2 AWG bare copper and bonded to a three quarter inch (3/4") by ten foot (10') long copper or copper-clad steel ground rod by exothermic welding, hydraulic crimping, or explosive crimping using a tap connector. Exothermic weld connections shall be used for all buried or subject to submersion connections. Explosive crimped connections and hydraulic crimping connections shall be located in access wells. The shields or armor on direct earth buried power cables shall be grounded on each end, but not at each splice.

b. Control cable shields shall be grounded at each end. Intermediate splices in control cables shall be insulated from ground to values equal to that of the original cable.

c. Telephone cable shields shall be grounded at one end only. The shield shall be insulated from ground equal to that of the original cable at each splice.

d. Coaxial cable shields shall be insulated from ground throughout the length of the cable run, or as shown on the drawings. These cable shields shall terminate at connectors mounted on metal bulkhead connector plates. These connector plates shall be a minimum of one quarter inch (1/4") thick and shall be constructed of tinned copper or other material compatible with the cable line connectors. The connectors shall provide a path to ground for cable shields except when the shield must be isolated for proper equipment operation. If external and internal cables are of a different size, the feed-through connectors at the plate may accomplish the connector size change.

The bulkhead connector plate shall be bonded to the earth electrode system with a 2/0 AWG insulated copper cable, colored green with a red tracer. The bulkhead connector plate shall also be bonded to building steel, where building steel is properly bonded to the earth electrode system. Exothermic welds or FAA approved pressure connectors shall be used for these connections.

3.16. CABLE GUARD WIRES

The contractor shall install cable guard wires to protect underground conductors from the effects of lightning discharges in accordance with FAA-STD-019e. All connections to the ground rods and guard wires shall be exothermic welds, in accordance with FAA-STD-019e.

3.17. CABLE TAGGING

All cables shall be tagged in each manhole, hand hole, junction box, demarcation cabinet or other such device with not less than two tags per cable, one near each duct entrance hole. Tags shall be attached to cable immediately after installation. Cable terminations and potheads shall be tagged as to function, i.e., facility, which it serves, or other pertinent data. Tags shall be circular in shape, two inch (2") minimum diameter and of not less than 0.020-inch thick copper or 0.0625 inch thick lead. Steel lettering dies, quarter inch (1/4") minimum character size, or the equivalent engraving process, shall be used to mark the tags. Each tag shall be securely attached to the cable using one eight inch (1/8") inch nylon cord. Tags shall be marked with an abbreviation of the name of the facility or facilities served by the cable plus an appropriate letter. "P", "T", "C", or "R" (Power, Telephone, Control, or Radio Frequency respectively). Where telephone type cable is used for control functions it shall be marked "T" instead of "C". Where more than one identical cable is used to serve the same facility, they may be bundled under one tag unless job plans state otherwise.

3.18. TRENCH MARKING TAPE

All buried cable shall be marked with trench marking tape. Tape shall be six inches (6") wide minimum and shall run continuous in the cable trench six inches (6") below the surface or as indicated on the project plans. Marking tape shall be bright red, orange, or yellow "Terra Tape" as manufactured by Reef Industries, Houston, Texas or approved equal.

3.19. MARKERS

All manholes and hand holes shall be identified by "FAA-Power" or "FAA-Control" markings cast in the steel manhole or hand hole cover, or so identified with a die stamped, nominal one sixteenth inch (1/16") minimum thickness copper plate, brazed or fastened to the cover with a minimum of two 10-32 brass machine screws.

Direct earth burial cables shall be marked every two hundred feet (200') along a cable run, at each change of direction of the cable and at each cable splice. Markers shall be either concrete or electronic, or a combination of both as specified by the contract documents.

3.19.1. Concrete Markers. Concrete slab markers, two feet (2') square and six inches (6") thick, shall be installed within 24 hours of the final backfill of the cable trench. The markers shall be installed flat in the ground with the top approximately one inch (1") above the finished grade. After the concrete marker has set a minimum of 24 hours, the top surface shall be painted bright orange with paint manufactured specifically for uncured exterior concrete. Markers shall not be installed in concrete or asphalt surfaces. Each cable marker shall have the following information impressed upon its top surface:

a. The word "CABLE."

b. Name of facility served, i.e., "ASR," "VORTAC," ALS," etc.

c. The type of cable installed shall be marked with the following abbreviations "P" for Power, "C" for Control, "T" for Telephone, and "R" for Coaxial (Radio Frequency). The designation of all type cables installed shall be shown on the marker.

d. An arrow to indicate the direction or change of direction of the cable run.

e. Any additional information as defined by the contract drawings.

f. The contractor shall obtain approval from the FAA for the information to be impressed on the cable marker and for the method of impression. The letters shall be four inches (4") high, three inches (3") wide and one half inch (1/2") deep.

All cable and cable markers shall be coded with applicable color coding standards, as applicable to the locality. If no standard applies, use the APWA Color Codes shown in the following table.

COLOR CODE	TYPE OF UNDERGROUND UTILITY
RED	**Electric power lines, cables or conduits, and lighting cables**
YELLOW	**Gas, oil, steam, petroleum or other hazardous liquid or gaseous materials**
ORANGE	**Communications, cable TV, alarm or signal lines, cables, or conduits**
BLUE	**Water, irrigation, and slurry lines**
GREEN	**Sewers, storm sewer facilities and utilities, or their drains lines**
WHITE	**Proposed excavation**
PINK	**Temporary survey marking**

The location of the ends of ducts shall be marked with concrete markers 2 feet square and 6 inches thick. The duct markers are to be installed in the same manner as cable markers, except the following shall be impressed upon their top surface:

a. The word, "DUCT."

b. Name of facility served, i.e., "ASR," "VORTAC," "ALS," etc.

c. An arrow to indicate the direction or the change in direction of the cable route.

d. The number of conduits and the type of conduits; e.g., 4-P/2-C.

e. Any additional information as directed by the COTR.

3.19.2. Electronic Markers. All underground cable trenches shall be marked using a four inch (4") electronic ball marker system as manufactured by 3M Corporation.

3.19.2.1. Control, Communications and Coaxial Cable Markers
The cable route shall be marked by an electronic marker using ScotchMark four inch (4") ball markers, model 1401 (orange) manufactured by 3M Corp. The ball markers shall be placed at intervals not to exceed two hundred feet (200') and at points four feet (4') before, four feet (4') after and in the middle of each change of direction. When control, communications or coaxial cables are installed in the same trench as power cables, the trench shall be marked utilizing the markers for power cables. Text on the drawings will indicate the separate cables contained in each trench. All ball markers shall be placed in the trench while backfilling. All ball markers shall be placed at depth of twelve inches (12") below finished grade and directly above the cable.

3.19.2.3. Power Cable Markers
Power cable trenches shall be marked by an electronic marker system using ScotchMark 4-inch ball markers model 1402 (red) manufactured by 3M Corp. The ball markers shall be placed at intervals not to exceed two hundred feet (200') and at points four feet (4') before, four feet (4') after and in the middle of each change of direction. All ball markers shall be placed in the trench while backfilling. All ball markers shall be placed at a depth of twelve inches (12") below finished grade and directly above the cable.

3.19.2.4. Special Purpose Markers
Special Purpose markers are used to indicate points of additional information. At a minimum, markers shall indicate the location of buried splices and the entrances of duct banks. Other significant points will be required at the discretion of the CM. Special purpose points shall be marked using a ScotchMark four inch (4") ball marker model 1403 (blue) manufactured by 3M Corp. All ball markers shall be placed at a depth of twelve inches (12") below finished grade and directly above the cable.

3.20. SURVEY REQUIREMENTS

Prior to backfilling the cable trenches, the contractor shall record all required survey data and deliver to the FAA a finished survey plotted on survey maps, following the conventions used by the FAA, in accordance with Quality Level B of CI/ASCE 38-02. The contractor shall also record and provide data on the types and locations of all cables abandoned in place as part of this contract. The collected data will then be provided to the FAA.

3.20.1. Survey Points. Prior to backfilling the cable trenches, the contractor shall survey points along the entire cable route from end to end. In some cases where the contractor splices into an existing cable and reroutes only a portion of the cable run he is only required to survey and provide drawings for the portion that he replaced or rerouted. The points shall be at intervals of not greater than two hundred feet (200'). Where the cable changes direction, the FAA may require additional points to accurately describe the cable route. Where the cable terminates to a building, a transformer, an antenna, a light bar, an outside demarcation cabinet, switch rack or other similar device the survey shall include the four corners of the device or facility where it terminates. A tolerance of plus or minus five inches (± 5") will be acceptable for describing the cable path.

Survey points shall include but are not limited to all markers placed in or on top of the cable trenches and all duct bank manholes and handholes. All duct banks shall be surveyed and plotted on the drawings. Those ducts that are installed for future use shall have text box pointing to them indicating that they are future use duct banks. The markers shall be identified on the drawings by a small circle with a "C" in the center for control cable, "P" for power cable, "R" for coaxial cable, "S" for special purpose points and "T" for telephone. Special purpose points will be used to indicate points such as splices or entrances to duct banks. Splices made in manholes and handholes shall be shown on the cable drawing. In the case of a duct bank where the duct bank is not a straight line between the manholes or handholes enough markers of the specified type shall be installed to accurately depict the routing of the duct bank. Survey points shall be taken

and plotted on the drawings for each of the ball markers. Manholes shall be identified by a small square with a "MH" in the center. Handholes shall be identified by a small square with a "HH" in the center. Where manhole and handhole numbers are on the contract drawings they shall also be called out on the completed cable drawing.

All special purpose points shall be accompanied by accurate text to describe the function of the specific point. All trenches shall be identified with text boxes pointing to the trench indicating what is in the trench. If there are several cables in the trench, all cables shall be called out. Power cables shall be identified by the actual working voltage of the cable and not by the cable insulation rating. The number of pairs contained in the cable shall identify control cables. Anything unusual, peculiar or unique about the cable runs shall also be called out in the drawing.

3.21. SPLICES

Whenever possible, splices are to be avoided, and cable shall be continuous run between end connections. Splices on multiple cables in a trench shall be staggered. Cable ends to be spliced shall be kept free from moisture by using tape or caps. All cable runs shall be given continuity and insulation resistance tests per this specification at the completion of each splice. In addition, at the completion of the installation of each cable section (from termination to termination), the cable section shall be subjected to a 50/60Hz partial discharge test in accordance with IEEE 400.3 at up to 2.5 times operating voltage level for a duration not to exceed 30 seconds, while the cable section is disconnected from the rest of the system. Any partial discharge within a splice shall comply with the requirements of IEEE 404. Splices are not to be drawn inside of any conduit or duct.

3.21.1. Cable Splicing

Splices outside of manholes and handholes shall be direct earth buried unless otherwise specified in the project plans. Each cable splicer shall be qualified in making cable splices and in the use of specified cable splicing kits. The FAA may request a test splice of each type and voltage rating from each cable splicer. The contractor shall obtain approval of the splice and cable splicer from the FAA prior to making any field splices. All cable splicing methods and materials shall be of a type recommended by the splicing materials manufacturer for the cable to be spliced. All splices shall be as follows.

a. Medium voltage power cables (2000V and above). Use either cold-shrink splice kits, such as those manufactured by 3M or equivalent, or heat-shrink splice kits, such as those manufactured by Tyco/Raychem or equivalent. The contractor shall make sure that the proper kit is used for each application.

b. Power cables 600 volts and below. Use heavy-wall self-sealing heat-shrinkable tubing manufactured by Raychem Corporation, Energy Division, Part No. "WCSM", or approved equal. This product shall meet ANSI-C119.1-2006.

c. Control and telephone cables. Use standard splicing kits as manufactured by Raychem Corporation. Telecommunications Division, "XAGA 1650 series "

heat shrinkable joint closure (Refer to Table III), or approved equal. Type "D" polyurethane re-enterable encapsulant shall be used for sealing the wire bundle and cable core moisture blockage. An approved encapsulant is 4442-D 3M and is available from Graybar Supply Co. Shield connectors 4460-D 3M are needed to complete the splice and are also available from Graybar Supply Co. Amp Picabond type connectors #61292-2 are preferred for splicing telephone pair conductors. Cable preparation shall include, and particular attention shall be given to cleaning the grease filling from the splice area. Use a trichloroethane type solvent. The products used shall meet Specification ATT Publication #55004.

TABLE III. Suggested Control Cable Splice Kits

CABLE SIZE	JOINT CLOSURE KIT
6-25 PAIR #19	XAGA-1650-A2
50 PAIR	XAGA-1650-B2
100 PAIR	XAGA-1650-C2

NOTE: (The contractor is responsible to insure splice kits are the correct kits for the application. The kit numbers supplied in Table III may change from time to time. Contact Raychem or go to the Raychem web site.)

d. Coaxial cable (non-pressurized). No splices will be allowed in coaxial cables.

e. Connectors, power cable. Connections of cable conductors shall be made using crimp connectors utilizing a crimping tool designed to make a complete crimp before the tool can be removed.

f. Connectors, control and telephone cable. Amp Picabond type Connectors #61292-2 are preferred for splicing telephone pair conductors, because of their small size. Type UR or ULG connectors, as manufactured by 3M, may also be used. Other connectors may be used with prior approval. Control cable connectors shall be crimp or solder type. If crimp connectors are used, they must be installed with a ratchet type tool, which requires full compression before it releases. Insulation for connectors may be either factory applied or field taped.

g. Cable armor and shields. Armor and shield may be folded back prior to splicing, then reinstalled across the splice and bonded by the use of approved bonding clips, or soldering when copper material is used. If the armor is galvanized material, it shall be bolted. Excess threads should be cut from bolts and wrapped with butyl tape so there are no sharp projections prior to using heat-shrink tubing.

h. Evaluation of equivalent products. If the contractor proposes to use equivalent products, the contractor shall submit samples of the product

drawings showing details of the splicing methods, and a statement of the experience the contractor has in making splices with the proposed product at least four calendar weeks prior to the scheduled use of the equivalent product. In addition, products shall meet the latest editions of standards in Table IV, "Cable Splicing Specification Equivalents".

Table IV. Cable Splicing Specification Equivalents

PRODUCT IDENTIFIED IN PARAGRAPH	APPLICATION STANDARD	LEVEL OF ACCEPTANCE
***	1. IEEE-404 Standard for Power Cable Joints	Meet or Exceed
*****	2. IEEE-48 Standard for Cable Terminations	Meet or Exceed
******	3. ANSI C119.2 Water Immersion Test	Meet or Exceed
*****	Same as 3.6.2a.	Meet or Exceed
*****	ANSI C119.1 Sealed Insulated Underground Connector System Rated 600 Volts.	Meet or Exceed
*****	IEEE-386 Standard for Separable Insulated Connectors	Meet or Exceed

3.22. GOVERNMENT FURNISHED CABLE

Government furnished cable will be delivered to the contractor in accordance with the provisions of the contract. The contractor shall test the cable in accordance with paragraph 4.1 and report electrical or physical cable defects within two weeks of cable receipt. If adequate cable lengths are unavailable for testing on the reel, a visual inspection shall be made and any damage reported to the FAA. The required tests shall then be made immediately after unreeling. Hidden defects discovered when installing the cable shall be reported to the FAA in accordance with the contract provisions.

3.23. CONTRACTOR-FURNISHED CABLE

Single and multi-conductor power, control and signal cables furnished by the contractor shall conform to the applicable following FAA specifications.

FAA-E-2013 for single-and multi-conductor power cables used in exterior 600 volt applications;

FAA-E-2042 for use in electrical control applications;

FAA-E-2072 for use in telephone communications;

FAA-E-2171 -2271, -2524, -2619 as appropriate for coaxial communications Cables.

FAA-E-2793 for single and multi-conductor power cables used in 2,000 to 35,000 volt applications;

L-824 Class C, 5 kV for airport single-conductor series lighting cable.

For applications where no FAA specification is appropriate, the cable shall meet the following minimum requirements:

a. Copper conductors.

b. Thermoplastic, thermosetting, or silicon rubber insulation.

c. Neoprene, polyethylene, or vinyl jacket for normal areas and PTFE (Teflon) jacket in areas exposed to fuel, oil, solvent or chemical leakage, excessive ground water or extremely acidic soil.

d. For rated voltages to 8 kV, insulation shall have a minimum continuous voltage withstanding capability of 4 times rated voltage (but not less than 150 volts). For rated voltages above 8 kV, insulation shall have a minimum continuous voltage withstanding capability of 3 times rated voltage. Cable voltage surge capabilities shall be 15 times rated voltage for voltages to 8 kV, 9 times rated voltage for voltages above 8 kV through 15 kV, and 7 times rated voltage for voltages above 15 kV through 25 kV. Whenever a cable is covered by applicable ICEA/NEMA specifications, the cable shall pass all the test requirements for such cable. In addition, the installed cable shall satisfy all after-installation tests specified in 4.1.

e. The pull strength of the completed cable(s) shall exceed the expected installation forces by a minimum of 50 percent.

4. QUALITY ASSURANCE PROVISIONS

4.1. CABLE TESTING

The contractor shall perform all cable testing in the presence of the FAA. The contractor shall furnish all necessary test instruments, except where otherwise indicated in the project plans (i.e., off-line partial discharge testing). Only currently calibrated

instruments shall be used for cable testing. A laboratory approved by the measurement instrument manufacturer shall have done instrument calibration. All cables shall be tested before installation, after each splice, and again upon completion of the installation. Off-line partial discharge testing shall constitute the final acceptance test after completion of the installation. All testing shall be completed on contractor-installed cable before connection is made to any existing cables. The FAA will test existing cables and provide the results to the contractor through the contracting officer prior to the contractor splicing or connecting cables he has installed to existing cables.

4.2. POWER CABLES ABOVE 2,000 VOLTS

Power cables rated above 2000 volts (shielded medium voltage power cables) shall be subjected, after installation but before connection to terminal equipment, to the following tests:

a. Continuity test for cable conductor, shield and armor, using an ohmmeter type instrument
b. Insulation resistance using a Megger type instrument shall be used at a voltage equal to the rms value of the cable operating voltage for a duration not to exceed five (5) minutes only as a means of determining whether the insulation has been compromised. The insulation resistance values may be affected by temperature, cable geometry, cable length and leakage along cable terminations. Terminations shall be thoroughly cleaned and, if possible, a guard circuit shall be used at the termination. The insulation resistance values obtained in the field may be used only as a means for screening good cable systems from questionable systems.
c. 50/60Hz, off-line partial discharge location test in accordance with IEEE 400.3, using a maximum test voltage of 2.0 to 2.5 times operating voltage level for a duration not to exceed 30 seconds. The off-line partial discharge test is the only reliable method for detecting defects inadvertently missed during factory tests, or defects introduced during transportation and installation, including flaws introduced while handling and splicing the cables. These defects may not show up in voltage withstand tests but would eventually cause undesirable service failures. The partial discharge test shall be conducted by a qualified subcontractor approved by FAA. This test shall identify the location and severity of any defect within the cable or its accessories.

4.2.2. Power Cables 600 Volts and Below. All power cables shall measure not less than 50 megohms resistance between conductors, and between conductors and ground. Measurements shall be taken at not less than 500 volts DC and not more than 600 volts DC.

4.3. 5,000 VOLT SERIES LIGHTING CABLES

After completing installation, each series loop with its connectors and lighting transformers shall be tested for insulation resistance. Test shall be conducted in accordance with paragraph 4.2 with both ends of each loop disconnected from the series cutouts at the substation, except for the following:

a. When the transformers cannot withstand a DC voltage of 10,000 volts, the test shall be performed at the highest allowable transformer voltage.

b. Depending upon the number of lighting transformers in the loop and their individual insulation resistances, the allowable loop insulation resistance may be reduced, based on the parallel summation of the cable and transformer insulation resistances. However, the cable insulation resistance shall never be less than the 50 megohms for a cable length of 10,000 ft or less.

   The insulation resistance (IR) of a cable can be estimated by the following equation:

   IR=K log (D/d)

   K= Specific insulation resistance in Mohms-1000 feet (i.e., for log(D/d)=10)
   D=diameter over the insulation
   d=diameter under insulation
   IR=insulation resistance in Mohms-1000 feet for a specific cable insulation.
   The formula for calculating the total insulation resistance to earth of several lengths of cable connected in series is: $1/R_1 + 1/R_2 + 1/R_3 + \ldots + 1/R_n = 1/R_T$. R_1 is the resistance of the first length of cable, R_2 the second length, etc. etc. and R_T is the total resistance of the connected lengths.

   As indicated by this formulas, the IR of a cable is inversely proportional to its length (i.e., the IR drops as length increases).

   For new XLPE and EPR insulated cables, the K factor at 60°F shall not be less than 20,000 Mohms-1000 feet.

With both ends of each loop disconnected from the series cutouts at the substation, each loop shall also be tested for loop resistance with the lighting transformers installed. The DC circuit resistance of each series loop shall be calculated as directed by the FAA.

The loop resistance shall be measured with a Wheatstone bridge or equivalent instrument and recorded. The measured resistance value shall not exceed the calculated resistance by more than 20 percent.

4.4. CONTROL AND TELEPHONE CABLES

After installation these cables shall comply with the requirements of Table V.

Table V. Control and Telephone Cable Conductors.

CABLE SIZE	MINIMUM NUMBER OF ACCEPTABLE CONDUCTORS
12 pair or less	All
13 – 25 pair	All, except 1 pair
Over 25 pair	All, except 2 pairs

4.4.1. Conductors
Acceptable conductors satisfactorily pass tests for
(a) continuity, (b) freedom from short circuits, and (c) a minimum of 50 megohms resistance between conductors and from each conductor to grounded shield when tested at not less than 500 volts DC.

4.4.2. Cable Testing. The contractor shall test the cable prior to installation and tag any defective conductor pairs that are found. The contractor shall notify the FAA of any unusable conductors found. These may be subtracted from the allowable number of accepted conductors specified in Table V, if the cable is government furnished.

Tests between unpaired conductors showing an insulation resistance below infinity on a 500-volt, 100-megohm, or equivalent insulation-measuring instrument shall be tabulated by the contractor and furnished to the FAA. This report shall indicate measured resistance values.

Should telephone cables include an extra conductor pair, and have one pair tagged as defective by the manufacturer, this extra conductor pair shall not be included in the minimum number of acceptable pairs listed in Table V.

4.5. COAXIAL CABLES
For all radio frequency cables the insulation and loop resistance shall be measured prior to installation. The results shall be recorded and furnished to the FAA. The insulation test shall be made between the center conductor and shield with a 500-volt DC instrument. The loop resistance test shall also be made in the same way, but with the center conductors shorted to the shield at the far end of the cable. This test shall be made with a bridge, ohmmeter, or other suitable instrument.

4.5.1. Testing After Installation. Coaxial cables shall be tested after installation. The conductor-to-shield and conductor-to-ground resistance shall exceed 50 megohms when measured at 500 volts DC. Loop resistance shall be within 10 percent of the measured values prior to installation, e.g., measured resistance per 1,000 feet of cable on a reel, and

multiplied by each 1,000 feet and fraction thereof of installed cable. Shield-to-ground insulation shall be measured and the results furnished to the FAA.

4.6. FAILURE OF CABLE UNDER TEST

If the contractor-furnished cable fails to meet test requirements after installation, the contractor shall repair or replace, at his expense, the sections of cable proven defective. If the cable is government furnished and the failure results from a manufacturer's defect not detectable prior to installation, the government will repair or replace the cable. If the government-furnished cable fails to meet test requirements after installation, due to faulty installation practices, the contractor shall repair or replace the sections of cable proven defective.

5. PREPARATION for DELIVERY – not applicable.

6. NOTES

The contents of the subparagraphs below are only for information. They are not contract requirements, and are not binding on either the Government or the contractor except to the extent they may be specified as such in other contract documents. Any reliance placed by the contractor on the information is wholly at the contractor's own risk.

6.1. The contract documents should define the required method or person by title for: "Approval by the FAA, Furnish the FAA, Report to the FAA" and similar statements within this specification, which is written to be generic.

6.2. The contractor should procure the services of a professional survey company.

6.3. The contractor should provide the survey company a knowledgeable and responsible representative to provide accurate and detailed information in order that the surveyor may include that information in the final drawing submission.

6.4. It is the intent of this specification to produce complete, accurate and factual drawings that will be used by FAA maintenance personnel to maintain the vital air traffic control facilities.

6.5. Brand names and specific products stated in this specification are to establish a base of known performance. Equivalents will be judged on their documented performance.

APPENDIX A

HIGH VOLTAGE/MEDIUM VOLTAGE ELECTRICIAN

CONCEPT

To troubleshoot, repair, install and service medium and high voltage electrical systems and associated equipment; to operate, inspect and perform preventive maintenance on medium and high voltage overhead and underground distribution systems; to prepare estimates, and plan and manage own projects within allotted budgets; and to perform related work as required.

DISTINGUISHING CHARACTERISTICS

High Voltage Electrician is a full journey level classification performing skilled high voltage electrical work in accordance with the techniques of the trade, based on completion of a recognized apprenticeship or its equivalent. This classification is distinguished from other classifications which may perform limited elements of electrical work by its focus on voltage systems above 600 volts and equipment, and by the scope of work and level of skill required. Positions at this level may direct the work of less skilled helpers on projects, and train apprentices; and may work independently or in conjunction with other crafts.

EXAMPLES OF DUTIES

The following duties are intended to illustrate examples of duties typically performed by incumbents in this classification. Individual incumbents may not perform all of the duties listed, nor are all of the duties an incumbent will perform necessarily listed.

- Troubleshoots and repairs overhead and underground distribution systems, including transformers, circuit interrupters, reclosers, capacitors, voltage regulators, medium voltage switches, utility poles, and supporting hardware;
- Replaces and installs medium voltage overhead and underground electrical circuits and terminations;
- Fabricates and installs a variety of components including but not limited to duct banks, cable runs, concrete pads for electrical equipment, risers, transformer banks, and low voltage electrical panels;
- Operates various components on the medium and high voltage distribution electrical system including isolation switches, interrupters, capacitor banks, transformers, overhead fused cutouts, and voltage regulators; isolates and clears sections of the system for maintenance, installation and load shedding;

- Inspects overhead and underground distribution systems, tests, and documents findings;
- Responds to emergency calls and takes necessary actions;
- Provides support for in-house capital and in-house projects with commissioning, testing and inspecting finished work;
- Uses personal protective equipment (PPE) such as hard hats, steel toe boots, safety glasses, respiratory protection, and fire retardant clothing;
- Uses other safety best practices such as hot sticks, lockout/tagout procedures, barricades, warning signs and devices to protect others;
- Directs the work of unskilled and semi-skilled helpers assisting in projects, assuring that proper safety practices are followed;
- Provides on the job training to apprentices;
- Operates a variety of testing, calibration and repair devices, tools and equipment including voltmeters, ammeters, ohmmeters, insulation resistance testers, high potential test sets, circuit breaker testers, etc.
- Coordinates work with customers, project managers, other crafts, and inspectors; inspects job sites and reviews detailed plans, drawings and oral directions to plan work;
- Prepares detailed estimates including labor and materials, and prepares lists of materials;
- Assists other crafts as needed;
- Maintains tools and equipment;
- Maintains current knowledge of equipment and materials through self-study and training;
- Prepares and maintains a variety of records and paperwork regarding work performed.

KNOWLEDGE AND SKILLS REQUIRED

Knowledge of:

- Electrical theory and terminology.

- Methods, materials, tools and equipment used in the maintenance, repair, and testing of high and medium voltage overhead and underground systems, and associated equipment.

- Safety and safe working practices pertaining to high voltage electrical work, including ensuring clearances, and working on energized lines and equipment.

- Laws, codes and regulations pertaining to high voltage electrical work, including NEC, IEEE, GO 95, and GO 128.

- Mathematics used in electrical calculations including algebra.

- Job planning and basic estimating.

Skill in:

- Performing repairs, fabrication, operations and maintenance of medium and high voltage electrical systems and associated equipment, especially cable systems.

- Using testing equipment, and troubleshooting complex electrical problems and developing effective resolutions.

- Operating and maintaining tools and equipment of the trade.

- Establishing and maintaining effective working relationships with those contacted in the course of the work such as customers, project managers, inspectors, and other crafts, including assisting others and working cooperatively.

- Maintaining records related to work performed including use of computers.

- Reading and interpreting plans, diagrams, drawings, instructions, and related technical materials.

- Planning and directing the work of semi-skilled and apprentice workers.

ILLUSTRATIVE EDUCATION AND EXPERIENCE

A typical way of acquiring the above required knowledge and skills would be equivalent to:

- certificate of completion of a recognized apprenticeship;
- accredited trade school;
- equivalent amount of experience and training comparable to journey level crafts status as a High Voltage Electrician.

OTHER REQUIREMENTS

- Must possess a valid driver's license and have a satisfactory driving record.

- Must be willing/able to work overtime, shifts and/or emergency call-in according to the needs of the unit to which assigned.
- Must be able to successfully pass a background investigation.